Things of science

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SILK

Unit No. 264

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SILK

This unit of THINGS of science consists of a silk cocoon, raw silk filament, finished silk thread, two pieces of finished silk material and this explanatory leaflet.

You are all familiar with silk which has been a symbol of elegance and beauty since its discovery more than 4,000 years ago. According to legend, the 14-year old bride of the Chinese Emperor Huang-ti, in 2640 B.C., was the first to unravel the fine silk thread from a cocoon and was the inventor of the silk reel that joins the delicate filaments into thread thick enough for weaving. The secret of the silk cocoon was guarded by the Chinese successfully for nearly 3,000 years.

It was not until 300 A.D. that Japan, now the foremost producer of silk, uncovered the mystery of silk.

In 550 A.D. the West saw the silkworm for the first time. Byzantine Emperor Justinian sent two monks to China, who at the risk of their lives stole mulberry seeds and silkworm eggs by hiding them in their walking staffs. Silk fabrics woven on the Imperial Byzantine looms still exist today.

Silk in ancient times was difficult to obtain and worth its weight in gold.

Transported by perilous silk routes across the heart of Asia by camel-back, it was traded at the market place in Damascus. Here the coveted silk was traded for Western luxuries.

Gradually the culture of silk moved westward and by the 12th and 13th Centuries Italy had become the silk center of the West. In the 17th Century France was challenging Italy in leadership and the looms established in Lyons during that period are still famous for the beauty of their weaving.

The first silk mill was erected in America in 1810 and today the United States imports more raw silk than any other country in the world. Some of the most beautiful silk fabrics are now woven in American looms.

The silk that Julius Caesar had once restricted to his exclusive use is now available to every woman.

The materials in this unit will help you understand how silk is produced and its processing into the many varieties of one of the loveliest materials now manufactured.

For over 1,500 years Japan has developed the science of sericulture (the raising of silkworms), but the industry was confined to manufacture for local use

until the last century when Japan opened her trade to the Western countries. Since then, by adopting modern science and technology Japan has become the leading producer of raw silk in the world.

Experiment 1. First identify the specimens in this THINGS of science unit.

COCOON—White oval case spun by the silkworm.

RAW SILK—Twisted skein of unfinished raw silk reeled off from the cocoon.

FINISHED SILK THREAD—Spool of silk sewing thread.

DYED SILK—Piece of dark blue habutai silk.

WHITE SILK—Piece of bleached habutai.

The specimens in your unit except for the spool of finished silk thread were all imported from Japan for this unit by the International Silk Association. The finished silk thread was supplied by Belding Corticelli, 1407 Broadway, New York 18, N. Y.

Experiment 2. Take the cocoon from your unit and feel how firm and hard it is and at the same time how light in weight. Notice the extremely fine filaments on the surface. The whole cocoon is made up of these fine filaments spun by the silkworm to enclose itself for protec-

tion during its metamorphosis or change into a chrysalis or pupa and then into a moth.

Experiment 3. Shake the cocoon. The rattle you hear is made by the dried up chrysalis which was prevented from developing into a moth and is still contained within the cocoon.

SERICULTURE

The raising of silkworms and their care is known as sericulture. Much research has been done through the years in the care and breeding of the silkworm to produce filaments of great length and quality.

The silkworm that produced the silk cocoon in this unit is the caterpillar of the silk moth *Bombyx mori.* The caterpillar of this moth feeds on mulberry leaves. One of the reasons sericulture has flourished in Japan is that mulberry trees grow well in the mild climate of that country and the best quality silk comes from worms fed only on mulberry leaves.

There are other species of silkworm, such as the type that produces the wild silk known as Tussah in the northern part of China, Manchuria and India. These caterpillars feed on oak leaves producing a strong rugged fiber.

The breed of silkworm most widely used in Japan is a Chinese-Japanese hybrid which produces cocoons having continuous filaments of up to 3,000 feet long.

The female silk moth *Bombyx mori* measures about two inches across its wings. After emerging from the cocoon it immediately mates and lays from 300 to 400 eggs about the size of the head of a pin or turnip seed within three to four hours. Fig. 1 shows a silk moth on a mulberry leaf laying eggs.

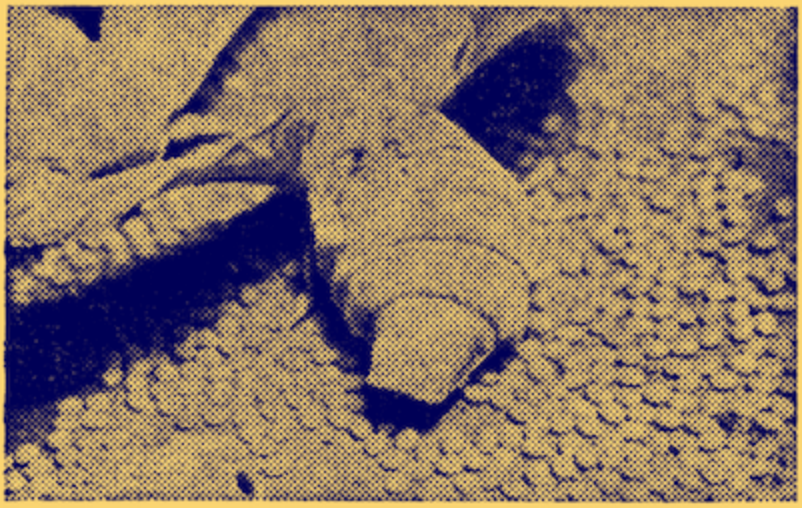

Fig. 1

The eggs are collected and put into cold storage, after testing to be sure they are perfect. In the early spring of the following year when the mulberry trees begin to leaf they are taken out and incubated. The eggs hatch in a week or so into tiny hairy ant-like silkworms about one-tenth of an inch long.

Silk moths are of two general groups, the monovoltines and the polyovoltines. The monovoltines complete a life cycle only once a year under normal conditions. The *Bombyx mori* is of this variety. The eggs of these moths must be subjected to severe cold, or hibernation, as in cold storage before they will hatch by incubation.

The polyovoltines complete several life cycles within a year. The eggs of these silk moths hatch within two weeks after being laid and do not go through the long hibernation of the monovoltines. The silk of the polyovoltines are not of the quality or strength of that of the monovoltines.

It has been discovered, however, that by artificial means the monovoltines can be induced to complete more than one cycle a year. By treating the eggs with dilute hydrochloric acid the embryo within reacts as if it has undergone hibernation. In certain sections of Japan where mulberry leaves are always available, two crops of *Bombyx mori* are raised each year, one in the spring and one in the fall, doubling the silk production.

The worms are kept under rigidly clean conditions on trays which must be refilled with fresh mulberry leaves every

two or three hours. The worms eat continuously and voraciously night and day for about five weeks. During this period they moult four times, shedding their old skins for another as they outgrow them.

The worms when they achieve their final growth are three or four inches in length and about one and one-half inches in circumference. When they stop eating and are ready to spin their cocoon they have attained a weight 10,000 times their birthweight. To attain this size they must consume an enormous amount of mulberry leaves. Enough silkworms to produce a pound of silk will eat 200 pounds of mulberry leaves before they are ready to spin their cocoons (see Fig. 2).

When the worm has eaten its fill, it creeps to straw or twigs provided, or the

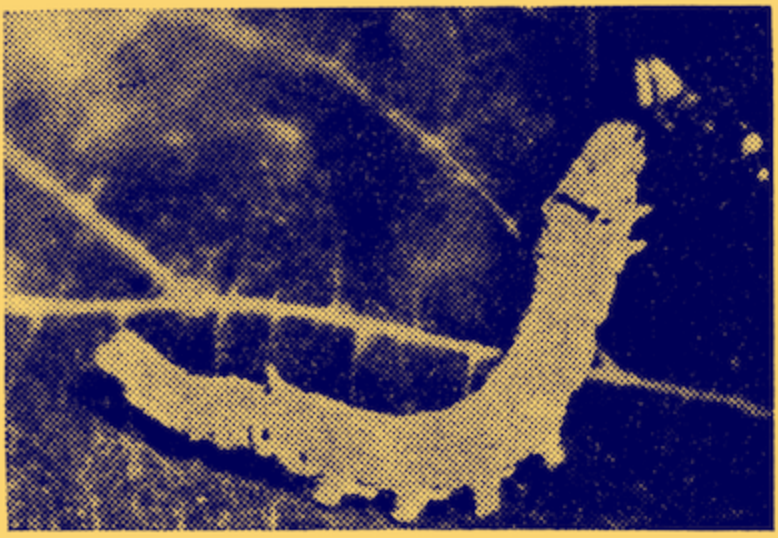

Fig. 2

worms are placed on a rack called the mountage. Each silkworm is given its own compartment in the mountage where it spins its cocoon (see Fig. 3).

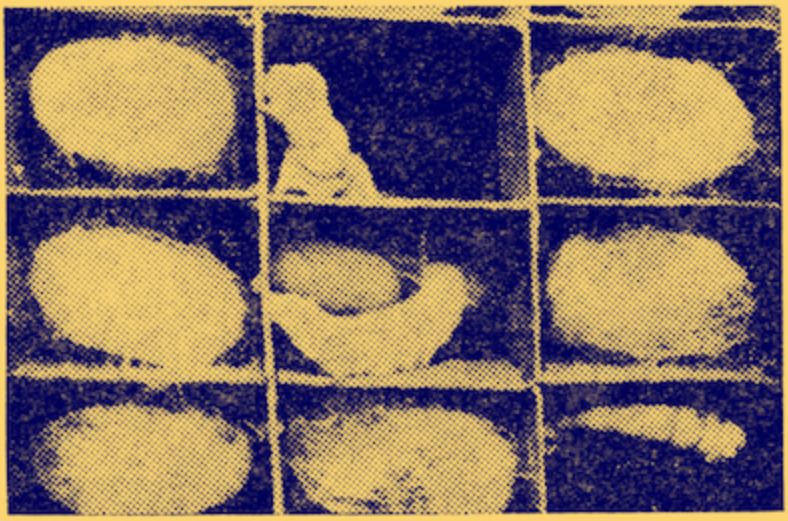

Fig. 3

The amount of silk a worm will produce is determined by the size of its silk glands (see Fig. 4) which run down the

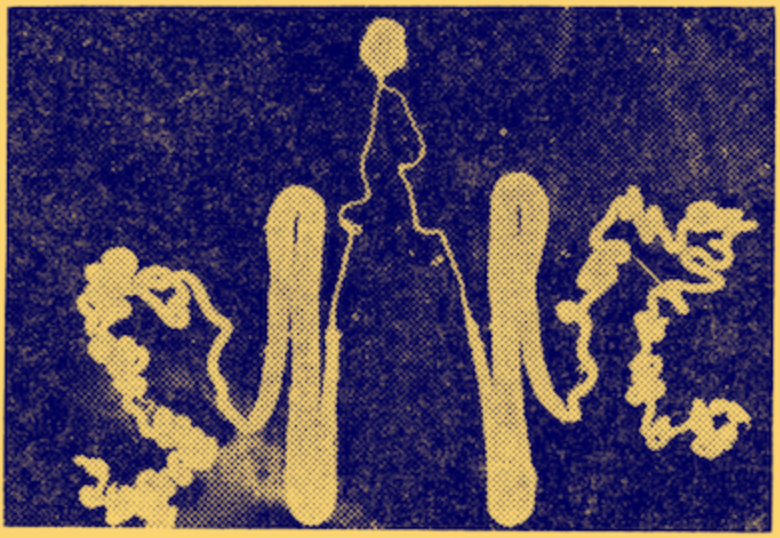

Fig. 4

entire length of its body. When the worm is ready to spin its cocoon it forces a viscous fluid through a small double orifice below the mouth called the spinneret, which on contact with the air solidifies to form a single strand of silky fiber. As the worm spins the filament, it secretes a gummy substance, sericin, which hardens and dries soon after it is exposed to air. This substance holds the filaments of silk together to form the hard protective covering or cocoon.

The worm first attaches itself to the twig, or the sides of the mountage, then, moving its head from side to side, it spins a continuous filament of silk in a series of figure eights enclosing itself in the cocoon. It continues working inside spinning the cocoon around itself.

Experiment 4. Take your cocoon and feel how hard and strong it is although very light. Look at the fine filaments of silk. Pull some off the cocoon. If you have a microscope examine the filaments under a powerful lens. See if you can distinguish the two fine fibers of which the filament is composed.

When the worm has finished constructing its protective covering, the cocoon, it changes into a chrysalis.

In the normal life of the silkworm,

after the cocoon has been spun, the worm turns into a chrysalis and the chrysalis into a moth. This transformation takes about two weeks. When the moth is ready to emerge from the cocoon it secretes a brownish alkaline solution which so weakens the filaments that they are easily broken and the moth pushes its way out of the cocoon. To prevent the moth from developing and thus cutting up the silk filaments it has spun, the cocoon is heat treated and the chrysalis killed.

REELING

Experiment 5. Reeling the silk which is done mostly by machines today, is the process of unwinding the filaments from the cocoon onto silk reels. You can do this for yourself with your cocoon.

Put the cocoon into a small pan of water and gradually heat until boiling. Turn the cocoon over and over in the water to be sure it is thoroughly wet. Boil for four or five minutes, then let stand until the water is cool enough to handle. The cocoon must be heated in water in order to soften the sericin.

When the water has cooled, brush the cocoon lightly with a toothbrush or other small brush to loosen the outside fibers. Pick off the loosened filaments gently. Lift

the cocoon occasionally by these loose fibers and drop into the water again, picking off the outside filaments as they are loosened. Set these filaments aside.

Repeat this process until only a single filament is unwound from the cocoon instead of the many loose ends. This will require a great deal of patience. Do not hurry.

Experiment 6. Obtain a piece of dark-colored stiff paper or cardboard about two by four inches in size. The paper should be dark in order to see the fine filaments of silk clearly.

When the single fiber is obtained, carefully unwind for about 10 inches. This filament, fine as a spider's web, is true raw silk. Take the end and wind it around the cardboard. Continue winding the thread from the cocoon by turning the cardboard over and over.

Experiment 7. If you wish, you can construct a simple reel for use in winding up the silk like the one shown in Fig. 5. Take two metal coat hangers that will bend and cut easily with wire cutters. Cut off the hooks of both hangers about an inch below the twisted part. Straighten out the wires with pliers or a vise. Cut one of the wires in half for the stand. From the second wire, cut a piece about

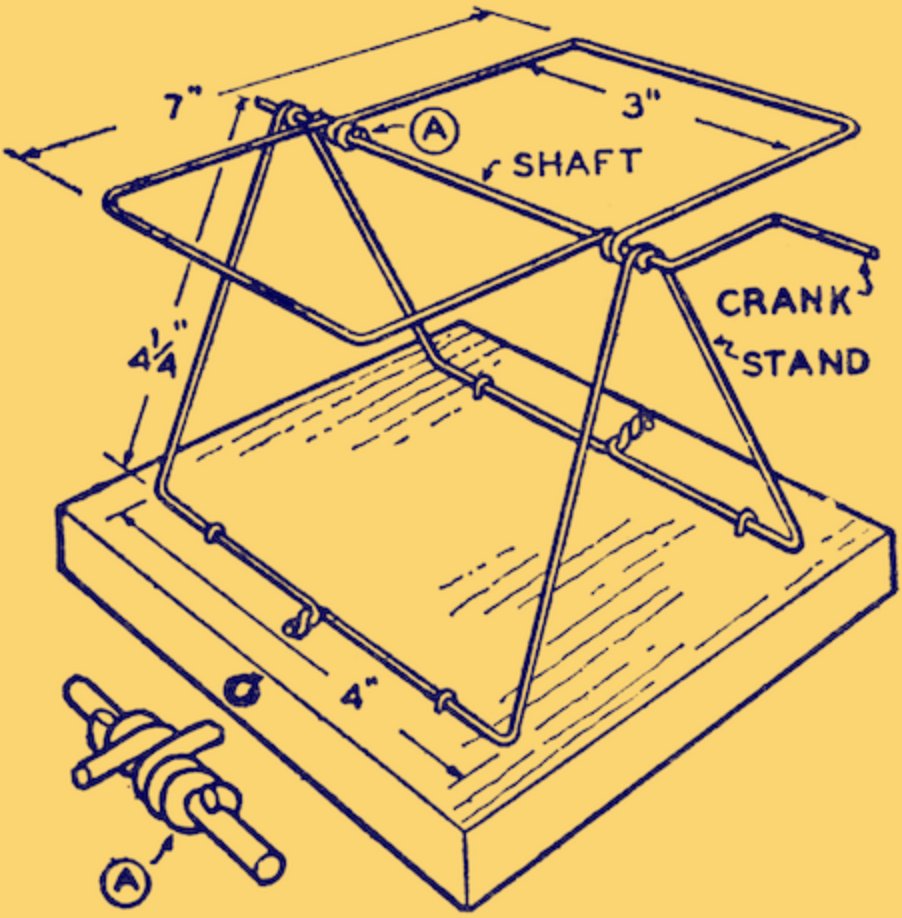

Fig. 5

ten inches long and bend one end to form a crank.

Make the stand first. Using the crank as a guide, twist the midpoint of one of the medium length pieces around the wire crank, thus forming a bearing in which the crank turns. Bend each leg inward at right angles to form the feet, being sure to make both equal in length. Duplicate with the second wire to produce the second support and bearing. Push the crank into both bearings and adjust the

wires, if needed, to make sure the crank turns freely, then twist the foot wires together where they overlap.

Tack or staple the stand to a suitable board and insert a screw eye on the side to serve as a guide for the silk thread. Now you have completed the stand and base as shown in Fig. 5.

Slip the crank from the bearings. Twist the remaining length of wire at its midpoint tightly around the crank, making two turns. Bring off the free ends at right angles to the crank. Shape the two legs of the reel, forming a winding space of about three inches in width, and carry the wires back toward the crankshaft.

Check both legs to get them as true as possible, then use a pair of pliers to grasp firmly one of the wires together with the crankshaft and twist the wire around the shaft as indicated at A. Repeat with the second leg of wire to complete the reel.

If the reel tends to slip on the crankshaft, place it on a hard surface and strike the wire twists several times with a hammer. This will cause the wires to bite into each other, and prevent slippage between crank and reel. Slip the crank end into the stand, then insert the free end to complete the winding reel. If the handle

turns freely, your reel is ready to be used.

Experiment 8. Place the reel on a box close to the pan containing the cocoon which has now been placed on a table, so that the base of the reel is about an inch higher than the top of the pan and the screw eye on the side faces the pan. If the water has become cool, heat again. Work with the cocoon until you have unwound a single thread 18 inches to two feet long. Thread this through the screw eye and fasten to one of the wire arms of the reel. Turn the handle gently and wind the fiber up on the reel. Once you get it properly started, you should be able to run it for many yards without breaking the thread.

Experiment 9. When you have wound a fair amount of silk onto the reel, slip the reel from the base.

Slide the reeled silk off the wires or piece of cardboard and twist into a little hank. Be sure to do this before the fibers dry.

In actual practice a single filament of silk is too fine to be of practical use. Therefore, several cocoons are unwound at the same time. Their filaments are drawn together and as the sericin hardens, it binds the filaments into a single thread-like filament which is reeled and twisted

into skeins like the sample included in this unit.

This first reeling, a delicate process, was formerly done by hand, but today is done by machine in most filatures in Japan. The silk is reeled a second time into larger skeins of uniform weight. The skeins are then bundled for "books" and the books are packed into bales, the unit used in raw silk transactions.

Experiment 10. Compare the raw silk filament from your cocoon with the sample of raw silk in your unit. Take a piece of the silk filament you have reeled from your cocoon and pull it. Note its elasticity. Pull a little harder until it breaks. Observe how strong it is for such a fine fiber.

Now take a length of the raw silk specimen included in your unit. Does it break easily? Notice how much stronger this fiber is now that it is composed of several filaments twisted together.

Twist several lengths of filament from the cocoon together. Now pull on it. See how much stronger the thread has become.

Silk is the strongest natural fiber known. For this reason, cords of parachutes during World War II were made of silk. A filament of silk is even stronger than a filament of steel of the same size.

Take the discarded bits of silk that you have placed in a little pile. What happens to these pieces when they dry? What causes the threads to become stiff again?

Experiment 11. Feel the raw silk filament specimen included in your unit. Is it soft and limp or rather hard and stiff with a hair-like feel? Partially unwind some of the finished silk thread specimen. Notice the difference in texture and appearance between the finished and raw silk.

Although the raw silk filament has a bright sheen, only after the sericin has been removed completely does the real luster of silk appear.

The sericin in the raw silk is boiled off either before or after weaving. In processing, the skeins of raw silk are placed in mild soap suds to remove some of the natural gum. The silk goes through various other processes to give it smoothness and permanent twist. It is then dyed and wound on to spools.

Put the bits of silk fiber you have set aside into a pan with a little soapy water and boil for about 15 minutes. Rinse thoroughly in warm water. If the silk still feels gummy, boil a little longer until all the sericin has been removed. Dry the thread. The thread should now be soft

and white. Does the thread have a more beautiful luster?

Repeat the experiment with the specimen of raw silk filament in your unit. What are the results?

Experiment 12. Hold up the fine filaments to the light. Are they opaque or translucent?

When the cocoons are reeled off and throughout other phases of silk manufacture, a certain amount of waste occurs, such as the pieces of silk thread above. This waste silk is processed into a yarn that is soft and lustrous called spun silk. The famous Fuji silk of Japan is made from spun silk. In the manufacture of silk, spinning is a process applied only to spun silk, since the threads unlike cotton and wool, are already many yards long.

Experiment 13. You can completely reel the silk from the cocoon until you reach the center and the chrysalis, or squeeze the water from the cocoon and let it dry. Does the cocoon become hard again upon drying?

CHARACTERISTICS OF SILK FABRICS

Experiment 14. Take the piece of silk material and feel its texture. The most distinguishing characteristics of silk are that they are made of animal protein and

have extraordinarily long fibers.

Notice how light silk material is compared with other fabrics such as wool and cotton. It has a density of 1.31 while the density of wool is 1.32 and that of cotton 1.53.

Experiment 15. Examine the piece of silk and note its luster. Pearls and silk are both esteemed for their beautiful luster. The luster of silk is a natural property of the fiber and appears when the sericin is removed. The luster is not a reflection from the surface alone and thus does not have a metallic coldness. It is a property of each filament of which the material is composed.

Experiment 16. Does the silk feel warm or cold to the touch? Because silk both insulates heat and absorbs moisture, it feels warm in the winter and cool in the summer. It is very smooth and soft to the touch.

Some fibers, like wool, feel warm to the touch because the fuzzy fibers trap air which serves as an insulation, preventing loss of heat from the body, while some, like linen, feel cool because they readily allow the heat to escape.

Experiment 17. Unravel several threads from the blue fabric and gently tease them apart. Notice how fine the

individual fibers are. Compare them with the filaments you have reeled from the cocoon. As you can see, the threads of the fabric are made up of several filaments of silk twisted together. Depending upon the type of material, the number of filaments twisted together will vary. The raw silk after it has been reeled from the cocoons as a single thread are twisted into more substantial yarns suitable for weaving or knitting. This process is known as throwing.

Experiment 18. Every woven fabric consists of a warp and a woof or filling, the former running lengthwise of the cloth and the latter crossing at right angles alternately under and over. This interlacing is called the weave. The warp threads are firmly twisted and strong, while the filling threads are loosely twisted and have less strength.

The silk in your unit is habutai, a plain silk fabric made of non-twisted warp and filling. Hold the material up to the light. Can you distinguish the warp from the woof?

Experiment 19. Crush the piece of habutai with your hand. Does it spring back to its orignial shape? Does it crease easily? As silk is tenacious and elastic, it is next to wool in crease resistance among

the natural fibers. Thus it is popular as women's wear of various types.

Experiment 20. Spill a drop of water onto the dark blue habutai. Is the water immediately absorbed? Notice that although wet, the fabric does not feel particularly wet. Silk is said to absorb as much as 20% of its weight in moisture without feeling wet.

Notice how quickly it dries. How does its speed of drying compare with that of wool and cotton?

Experiment 21. Wet the entire fabric with cool or lukewarm water and let dry. Press with a warm not hot iron. Is the appearance of the silk material affected by washing and pressing?

Some silks, like the material in your unit, are washable, but others are not and must be dry cleaned in order to retain their beauty.

Experiment 22. Take your white piece of habutai. Notice its beautiful sheen and how closely woven the material is. Since the natural color of a natural fiber is never a true white, it must be bleached to produce a pure white cloth. The threads that make up this piece of material were first boiled in a concentrated bath of mild soap to remove the natural gum or sericin and then bleached to produce the pure white

color. In general, the bleaching agents are either a reducing agent such as sulfur dioxide or an oxidizing agent such as hydrogen peroxide.

Experiment 23. Take a few threads from the blue habutai. Separate them and notice that the dye has penetrated each piece of thread.

From ancient times, silk has been beautifully dyed. Silk as a protein or animal fiber has an affinity for almost any kind of dye. It takes dyes with a purity and clarity that makes possible a limitless range of exact colors.

Silk may be dyed before woven into fabric while it is still fiber. This is called "yarn dyeing." Or it may be dyed after the goods has been woven which is known as "piece dyeing." Habutai is piece dyed.

In piece dying the fabric is first degummed and then dyed with either a direct dye for pale colors or an acid dye when very bright colors are desired.

Habutai comes in different weights given in momme. Momme is a Japanese measure of weight for silks. The samples of habutai in your unit are six momme.

Experiment 24. Silk test. How can you tell whether you have a piece of real silk? Working over an ashtray for safety, hold

a lighted match beneath one corner of your piece of silk and let it burn slightly. The tiny balls that form on the edge as it burns are typical of pure silk. They are dry and crush easily.

Does the silk continue to burn when the flame is removed? Is there any burning odor? Silk will only scorch and shrink and will not burn continuously.

If other fibers are present, the thread will flame up and leave no ashes.

Experiment 25. Take a short length of your specimen of finished silk thread. Pull on it and see how strong it is. How does it compare in strength with cotton thread?

Because of its strength and durability, you will find treasured silk fabrics in some museums that were woven many hundreds of years ago.

Experiment 26. Notice how the silk thread is twisted. Untwist the threads and you will find that the thread is composed of many filaments of silk twisted together. Can you count them?

Experiment 27. To produce silk sewing thread, the raw silk is first twisted

and then degummed to remove impurities, such as sericin. The thread is then dyed and wound on spools or cards or into skeins according to its use.

You may wonder what is done with all the chrysalises that accumulate during silk production. In the Far East they are widely used to feed carp and eels. In some countries the oil is extracted to manufacture soap and the residue is used as agricultural fertilizer.

Appreciation is expressed to the International Silk Association (U.S.A.), Inc., 185 Madison Ave., New York 16, N. Y., for their cooperation in producing this unit.

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Production by Ruby Yoshioka

October 1962

Cut out label on other side and put on end of box

Things of science MEMBERSHIP

12 monthly experimental kits—$5.00
(Add $1 for outside U.S.A. addresses)